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(54) Title: DEVICE AND SYSTEM FOR MANAGEMENT OF BATTERY BACK UP POWER SOURCE
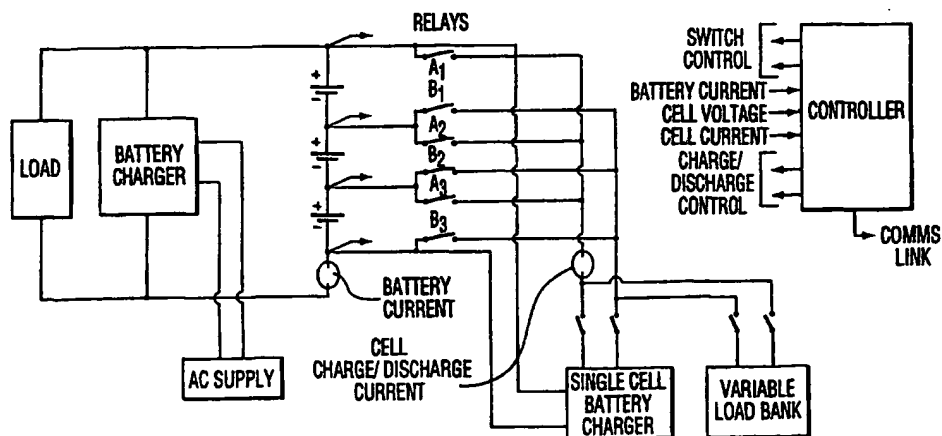
(57) Abstract

The invention relates to a device for managing battery packs from which it is powered by measuring and monitoring the operating capacity of individual battery modules in a battery pack. A programmable logic controller directs the selective closing of relays to allow individual battery modules to be load-tested using a variable discharge load unit, without compromising useful battery pack capacity. In a further embodiment, the invention can include, for each user, a network of battery management devices with two-way communications links to a central management location with computer based monitoring and control of all battery packs. In addition, a centre of expertise on battery technology is linked to the user networks.

DEVICE AND SYSTEM FOR MANAGEMENT OF BATTERY   BACK UP POWER
SOURCE

BACKGROUND TO THE INVENTION

The present invention relates to a device and system for the
management of a battery pack used as a power back-up for an
A.C. power source. The invention has particular application to
distributed telecommunication systems and enables the useful
capacity and health of a back-up battery power source of one
or more of the links in the telecom system to be monitored,
assessed and managed from a remote location.

The invention may be used in conjunction with any device or
network of devices which is battery-powered, or which uses a
battery pack as an alternative or back-up power source, such
as telecommunication relay sites, fibre optic sites, computers;
telecommunication or station batteries; telephone switching
facilities and portable test equipment.

Other potential applications include railway crossing and
switch systems; mobile electronic equipment battery packs used
in cellular telephones, computers, camcorders or electric
vehicles.

There is presently no fully reliable and accurate means for
determining the useful capacity of batteries, e.g. those used
as a back up for a primary AC power source for an instrument
or device which is situated at a remote location. In the event
of an AC power failure, it is essential that the DC battery
back-up power operate efficiently and at the required capacity.
To date, there has been no practical method to load test a
back-up battery at a remote site. Conventional devices measure
voltage, impedance, electrolyte specific gravity or other
battery characteristics, but do not provide the user with
direct information concerning the length of time the battery
will operate under load.

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SUMMARY OF THE INVENTION

The present invention obviates and mitigates the disadvantages inherent in the prior art by providing a device and system for directly assessing the useful capacity of a back-up battery, even where the battery is located at a remote site and without compromising the ability of the back-up battery to operate should there be an AC power failure during the battery testing. This objective is achieved by performing a sequential, individual assessment of each module which comprises a battery pack. Where used in this specification, the term "module" means one or more electrochemical cells.

A further advantage of the present invention arises from its capability to rejuvenate or boost the health of the battery module of certain chemistries, e.g. valve regulated lead acid (VRLA) or nickel/cadmium. The discharge/charge sequence which is carried out in order to assess and monitor the useful capacity of the module, also serves to better cycle the module.

In a preferred embodiment, the present invention provides a method for managing the back-up, battery power source of the distributed communications systems of the telecommunications industry. The invention enables individual telecom sites with fibre optic or radio equipment powered by systems containing back-up batteries to be operated with improved reliability and economy. The invention provides smart charging at the cell or module level, thus ensuring that the back-up battery pack always receives optimum charging. The invention further provides a continuously updated battery pack capacity based on cell or module discharge tests so that the individual sites on the telecom system are provided with a real time method of back-up battery network management. This network battery management system provides the user with information to

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optimize the efficiency and operability of the telecom system, in case of AC power failure, particularly if the there is a widespread or prolonged AC power outage.

In another embodiment, the invention provides a networked system which enables the back-up battery power source of a system with multiple battery installations to be effectively assessed, monitored and managed.

In a further embodiment, the invention provides a higher level of networked system which has as its hub, a master control center which integrates the application specific networks of users of the primary battery health management devices. This higher system will enable battery health to be expertly managed by enhancing the optimum servicing, reliability and economic operation of the back-up power systems, by providing a means whereby the capacity and health of a battery can be assessed, monitored and managed from a remote site without disruption of the battery circuit.

In one aspect, the invention provides a system for directly assessing the useful capacity of an online battery pack, comprising: a programmable logic controller operatively connected to a monitor circuit and to one or more battery modules comprising said battery pack, said monitor circuit comprising battery module charging means, and discharge load means; wherein said programmable logic controller selectively and sequentially opens and closes a plurality of relays which connect with said charging means and said discharge load means to alternatively define a discharge circuit which enables one of said modules to be discharged by said discharge load means under a predefined load, the useful capacity of said module being calculated by said programmable logic controller.

Preferably, the programmable logic controller comprises, or is operatively connected to at least one module voltage reader;

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battery pack current reader and module current reader; a switch controller to control said isolation relays; a controller for said variable discharge load means and said single module battery charger (charger/discharger controller).

In an additional aspect, the invention provides a method of sequentially assessing the operating capacity of a plurality of battery modules which define a battery pack, which comprises the steps of:

selecting one of said modules for assessment;

connecting said selected module to a variable discharge load means by closing relays which connect said module to said variable discharge load means;

measuring parameters which define the useful capacity of said module, while said module is under load;

disconnecting said selected module from said variable discharge load means by opening said relays and either; (a) connecting said selected module to a battery charger for recharging; and (b) reconnecting said selected module to said plurality of modules by the selective opening and closing of relays which connect said modules with said battery charger, and said variable discharge load;

wherein the coordination of all of the above steps is accomplished by the use of a programmable logic controller operatively comprising, in combination, at least one voltage reader; at least one battery pack current reader; at least one module current reader; and a switch controller to control the opening and closing of said relays.

A still further aspect of the invention provides a device for cycling batteries, comprising: a programmable logic controller

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operatively connected to a monitor circuit and to one or more
battery modules comprising said battery pack, said monitor
circuit comprising battery module charging means, and discharge
load means; wherein said programmable logic controller
selectively and sequentially opens and closes a plurality of
relays which connect with said charging means and said
discharge load means to alternatively define a discharge
circuit which enables one of said modules to be discharged by
said discharge load means under a predefined load.

An additional aspect of the invention provides a device for
enhancing the useful capacity and/or reducing the rate of
capacity loss of battery packs during service by using an
optimal recharge method on battery modules which comprise said
battery pack while said battery pack remains in service.

BRIEF DESCRIPTION OF THE DRAWINGS

Figure 1 is a schematic drawing of a preferred embodiment of
the invention, depicting a bridged connection circuit with
three modules;

Figure 2 is a schematic drawing of a further preferred
embodiment of the invention, depicting a bridged connection
circuit with "n" modules;

Figure 3 is a flowchart, schematically depicting operation of
the present invention;

Figure 4 is a schematic representation of the network
management system, being a further embodiment of the invention

Figure 5 is a schematic representation of an enhanced battery
management network, being a further embodiment of the invention

Figure 6 is a schematic drawing of an optional inserted
connection circuit

DESCRIPTION OF THE PREFERRED EMBODIMENT

The device of the present invention comprises a programmable
logic controller (PLC) or computer, coupled to a plurality of
multi-pole contactors, relays or solid state switching devices.

The device of the present invention may be used in conjunction
with rechargeable batteries of various chemical composition(s).
Some are sealed, others are flooded while others are valve-
regulated batteries. The typical chemistry of the batteries is
nickel/cadmium or lead-acid. The threshold voltage is
established having regard to the chemistry of the module.

The invention makes use of a bridged connection circuit, which
uses the principle of Kirchoff's law. Such an approach means
that the module which is being assessed need not be isolated
from the other modules comprising the battery pack. Figures 1
and 2 schematically represent a bridged connection. A bridged
circuit ensures that the electrical integrity of the battery
pack does not have to be broken in order to assess a single
module. Using the algorithm outlined in Figure 3, the capacity
of each module is sequentially calculated. The computer
controls the opening and closing of isolation relays, the
variable discharge load, as well as the module battery charger.
Further the computer senses the following: battery pack string
current and voltage, selected module charge/discharge current,
selected module voltage, ambient temperature, and battery pack
and/or module temperatures.

In Figure 2, the battery pack is shown as operatively connected
to a circuit comprising a load and a battery charger which
represents the primary power source and load for which the

battery pack is intended to provide back up. In order for the operative capacity of the back-up battery pack to be accurately measured, an allowance must be made for the current which flows from the primary power source into the battery pack. Use of Kirchoff's law, where $+/-$ ic $= +/-$ ip $+ +/-$ im where $+/-$ is positive for charge and negative for discharge, ic is module current, ip is current of the primary power circuit, and im is the current of the monitor device, enables the PLC to accurately and selectively measure the operative capacity of a given module within the battery pack without isolating or disengaging the module from the other modules which comprise the battery pack.

In operation, the controller selectively controls and co-ordinates the opening and closing of the switches which connect the battery charger and the variable discharge load. Where it is desired to measure the capacity of module or cell 1, isolation relays A1 and B1 are closed by command of the PLC, which then closes the relays which connect the variable discharge load with the battery. The discharge circuit which is thus created enables module or cell 1 to be discharged across the variable discharge load. Module current is measured by a reader within the circuit and fed back to the PLC. The PLC then causes the relays connecting the variable discharge load to the battery to open, and then closes the relays which connect the battery charger with the battery, thereby defining a charging circuit which recharges module 1 up to a threshold level which is consistent with the useful capacity of the other modules within the string. The procedure is then sequentially repeated for the remaining modules 2, 3,....n within the string.

Both the variable discharge load and battery charger output are adjusted according to the ambient battery and module temperature present to prevent battery damage. As well, the computer calculates the a-h (ampere-hour) capacity of each

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battery cell by integrating the discharge current over the time taken to reach the cut-off voltage threshold, or the energy capacity by the above integration of current times voltage over discharge time in hours. An alternative to using computer control of the variable discharge load and battery charger is direct control using linear circuits.

The means used to discharge the module may be a use specific variable discharge profile, constant current, constant resistance, or constant power. The method chosen will depend on the battery technology and the normal usage. To implement these methods, a variable resistor or the like is typically used.

The battery charger used to recharge the module under scrutiny may operate with a variety of algorithms including constant voltage/current, constant power and fast charge methods, including pulse charging.

In another preferred embodiment, relays A, B and C shown in Figures 2 and 3 may be replaced with solid state switches. However, solid state devices have the following characteristics which affect their suitability as replacements for relays:

1)   They tend to have a voltage drop when conducting current. In the inserted connection embodiment, the battery voltage under load would be reduced somewhat (a fraction of a volt). In the case of the bridged connection, this problem could be reduced by sensing battery voltages at the connection to the invention;

2)   Usually, two such solid state devices are needed for conducting in two directions. This increases the cost and complexity of the design;

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3)   Inputs are not isolated from outputs. This is
        somewhat problematic, since the monitor circuit
        needs to connect to points up and down the chain of
        modules making up the battery. If the battery
        voltage exceeds 30 volts, optical isolation is
        needed which further complicates the design.

Because of the problems outlined above, the use of solid state
switches as replacements for relays A, B and C would be
determined on a case by case basis. The most likely
applications would be for batteries having voltages below 30
volts or with currents below a few amperes, or where the
battery power levels are not much larger than the relay drive
requirements or where the use of electromechanical relays is
undesirable for other reasons.

The invention works as an integral part of the battery and is
designed to continue to operate in the event of an AC power
failure, and is able to provide a full load current to
substitute for a partially discharged module. This ensures that
the useful capacity of the battery pack is available and that
the module is protected from reverse-voltage damage.

So that no capacity is lost in the unlikely event of the module
battery charger failing when the isolated battery is
discharged, extra capacity is provided in the form of an
external module. This module will normally be float charged
by the invention. When the battery charger fails during a
discharge cycle, the external module or battery will be used
to power the battery charger.

The device of the present invention may further comprise an
alarm circuit which conveys an audible or visible warning
signal that the capacity of the battery pack has fallen below
useful level, which is particularly important where the battery
pack is being used as a back-up power source. This provides the

option of replacing individual batteries from the battery
instead of the whole pack, thereby providing a substantial
increase in battery pack life and a resulting decrease in
battery cost to the user.

As depicted by Figure 4, a plurality of the devices of the
present invention may be networked to permit the gathering of
data required for the effective management of systems with
multiple battery installations. The data collected from the
network is collated in one central data center. This eases the
problem of handling a large amount of data, enables the
analysis of standby power in large, complex systems, which
facilitates the making of rapid, well-informed decisions.

The embodiment shown in Figure 4 is a network of a plurality
battery health management devices (shown in Figures 1 or 2
herein) installed in conjunction with the battery back up power
sources for multiple, remote installations at sites on a
telecommunications or other similar network or system. The
remote battery health management devices are linked by
multiple communications or sub-networks to one or more
instations. The instation is equipped with suitable software
to enable the instation to log data from the remote
installations, generates alarms, produce statistics, group data
in tables for comparison, plot trends, extrapolate data,
generate reports and assist in record keeping.

The network shown in Figure 4 is application specific and
focuses on assisting in the routine health management
(including monitoring or power outages) of a remote battery,
such as remote cellular site. Because of the emphasis on
routine maintenance, the instation presents information such
as battery back time remaining, alarms, maintenance records,
site down time and power outages records. The system is
equipped with extensive database facilities that are used for
trending or to provide historical evidence of battery system
status.

A more sophisticated type of network is depicted in Figure 5 which comprises a plurality of individual battery health management installations and/or one or more application specific networks. All of the data collected at the individual installations or sites on this network are collated at a master control center which is equipped to manage battery maintenance of individual sites or systems by providing routine monitoring, and/or diagnostic assistance. The master control center may be staffed with personnel who are well acquainted with battery systems and maintenance and who are able to analyse problems as reflected by the incoming data, and who can further provide and implement constructive and remedial advice.

Optionally, a battery health management device shown as sites in the networks depicted in Figures 4 and 5 may use an inserted connection circuit, shown in Figure 6, in place of the bridged connection circuit shown in Figures 1 and 2.

An inserted connection circuit isolates one of the multiple modules in the battery pack (typically nine or eleven modules) by taking the cell out of the trickle/float charge circuit and then performing a discharge of the battery module which drains the energy of the module into variable discharge means such as a fixed resistance heater or similar device at the normal rated load capacity for that module. The PLC then records which module is being discharged, and how long it takes to discharge to a pre-programmed cut-off voltage. This information is then used to calculate how much energy the module was able to deliver under actual loaded conditions, thereby providing a real measure of its useful capacity. The information on module capacity is provided by way of a liquid crystal display, or similar means, and is given in watt-hours, ampere-hours; % of "as new" or the time to failure under load in minutes, whichever is required by the end user. When the measured capacity falls below a predefined threshold an alarm will be triggered, signalling the need for battery or module

replacement.   The battery module charger will be engaged to
recharge the discharged module.

In the inserted connection circuit shown in Figure 6, batteries
B1, B2 and B3 operate a charge/load circuit V.   Isolation
relays or contacts A and B connect an individual module to a
monitor circuit, while contact C closes the gap in the battery
created by the removal of the module. When relay contact C is
closed, the open circuit formed by the removal of the battery
module is closed, thereby allowing current to flow through the
charge/ load circuit.   When isolation relays A, B are closed,
an individual battery module can be isolated and connected to
the monitor circuit. The monitor circuit discharges the
isolated battery module and charges it as required using
feedback provided by the current sensor and the preset voltage
limits.

In the event of an AC mains failure, the relays must continue
to operate, otherwise a discharged module would be re-
introduced into the battery pack, reducing the useful capacity
of the battery pack.

The battery voltage would normally be (Vc * N-1) where Vc is
the nominal module voltage and N is the number of modules in
the battery. As the monitor circuit moves from one module to
the next, it causes a disruption in the battery pack voltage.
The battery pack momentarily goes open-circuit, then the
voltage jumps to Vc* N, then the battery pack goes open-circuit
again, then finally the voltage returns to (Vc * N-1).

The module to be measured is accordingly isolated from the
other modules comprising the battery pack by the selective
engagement of isolation relays. The module is then discharged,
its capacity is measured by the PLC as a function of the
discharge load, and it is then recharged. The isolated module
is temporarily unable to contribute to the output of the

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battery. The procedure is sequentially repeated, at selectable times, for the remaining modules which comprise the battery pack.

Only one battery module at a time is discharged so that the system is never more than 1/9 or 11% short of its maximum ampere-hour or watt-hour energy capacity (in the case of a nine cell battery pack). In the event of an AC power outage (i.e. a situation where the DC battery pack is engaged), when one of the modules is not fully charged, this module is kept out of the circuit by the use of isolation relays.

As an alternative to this method, an identical module to the battery modules in the battery pack can be added to the battery pack; for example, making a 9 module battery pack into a 10 module battery pack. In this case, the module battery charger will be powered from the battery pack.

In the event that there is a battery module with less useful capacity than the other modules in the pack, the invention can assess the state of health of the reduced capacity module and electrically isolate it from the rest of the battery pack, until such time as the rest of the pack has a poorer performing module than the isolated, reduced capacity module.

The embodiments of the invention in which an exclusive property
or privilege is claimed are defined as follows:

1.   A system for directly assessing the useful capacity of an
online battery pack, comprising: a programmable logic
controller operatively connected to a monitor circuit and to
one or more battery modules comprising said battery pack, said
monitor circuit comprising battery module charging means, and
discharge load means; wherein said programmable logic
controller selectively and sequentially opens and closes a
plurality of relays which connect with said charging means and
said discharge load means to alternatively define a discharge
circuit which enables one of said modules to be discharged by
said discharge load means under a predefined load, wherein data
with respect to the useful capacity of said module is
calculated by said programmable logic controller.

2.   A system as claimed in claim 1, further comprising means
for recording of said data calculated by said programmable
logic controller.

3.   The system as claimed in claim 1 or 2 wherein said relays
are selected from the group consisting of multi-pole relays,
contactors or solid state switching devices.

4.   A method of sequentially assessing the useful capacity of
a plurality of battery modules which define a battery pack,
which comprises the steps of:

selecting one of said modules for assessment;
connecting said selected module to a variable discharge load
means by closing relays which connect said module to said
variable discharge load means;

measuring parameters which define the useful capacity of said
module, while said module is under load;

determining whether said useful capacity meets a predefined
threshold for useful capacity;

disconnecting said selected module from said variable discharge
load means by opening said relays and either;

recharging said selected module by connecting said selected
module to a battery charger where said useful capacity meets
said predefined threshold; or generating a signal where said
useful capacity does not meet said predefined threshold;

wherein the above steps are coordinated by a programmable logic
controller operatively comprising, in combination, at least
one voltage reader; at least one battery current reader; at
least one module current reader; and a switch controller to
control the opening and closing of said relays.

5.   A device for cycling batteries while the battery remains
in service, comprising: a programmable logic controller
operatively connected to a monitor circuit and to one or more
battery modules comprising said battery pack, said monitor
circuit comprising battery module charging means, and discharge
load means; wherein said programmable logic controller
selectively and sequentially opens and closes a plurality of
relays which connect with said charging means and said
discharge load means to alternatively define a discharge
circuit which enables one of said modules to be discharged by
said discharge load means under a predefined load.

6.   A device for enhancing the useful capacity and/or reducing
the rate of capacity loss of battery packs during service by
using an optimal recharge method on battery modules which

comprise said battery pack while said battery pack remains in service.

7. A network system for the battery health management of remotely situate back up batteries consisting of a plurality of devices comprising a programmable logic controller operatively connected to a monitor circuit and to one or more battery modules comprising said battery pack, said monitor circuit comprising battery module charging means, and discharge load means; wherein said programmable logic controller selectively and sequentially opens and closes a plurality of relays which connect with said charging means and said discharge load means to alternatively define a discharge circuit which enables one of said modules to be discharged by said discharge load means under a predefined load, wherein data with respect to the useful capacity of said module is calculated by said programmable logic controller; wherein each of said devices are connected by a communications link to a data center which collates and processes data transmitted from said devices.
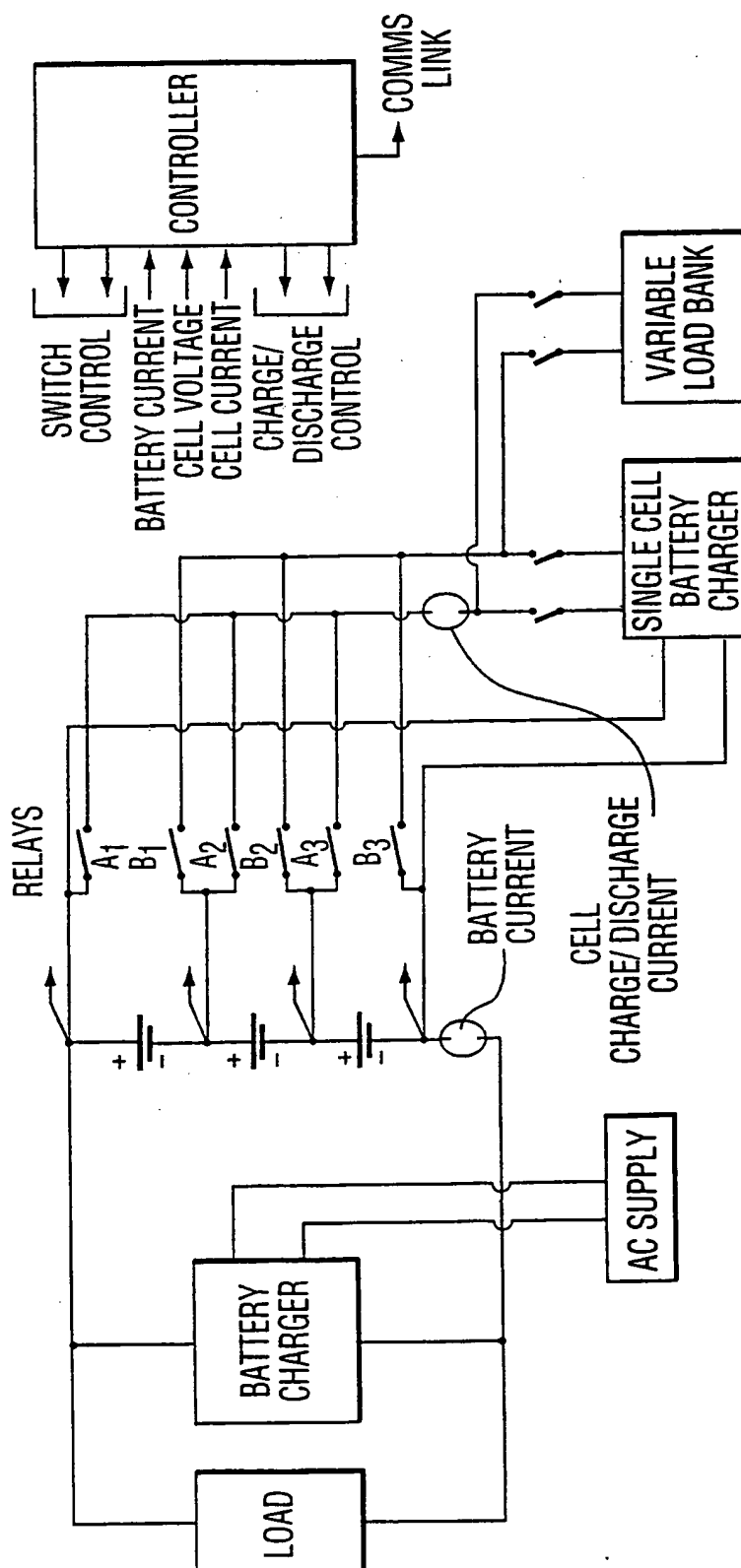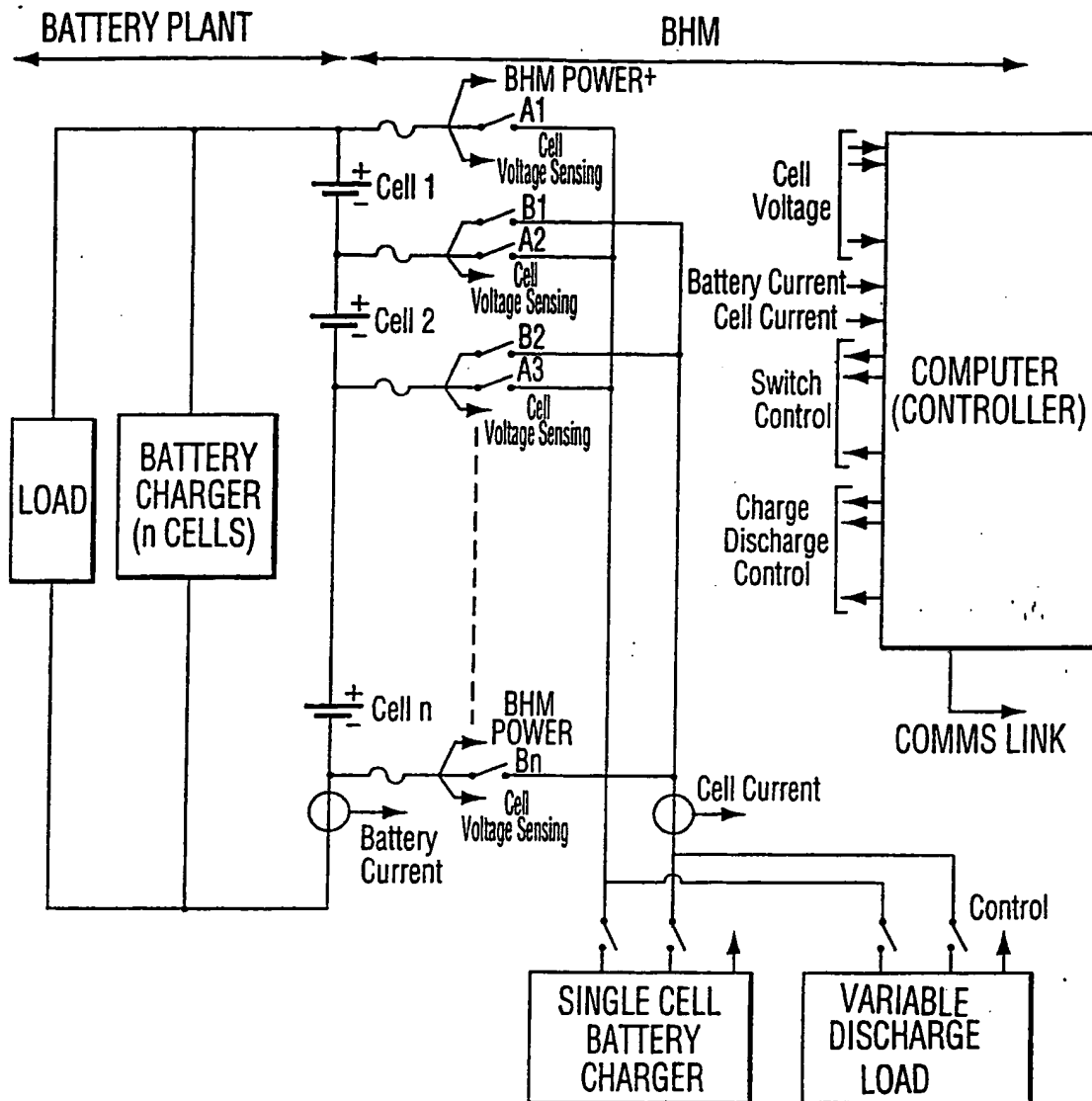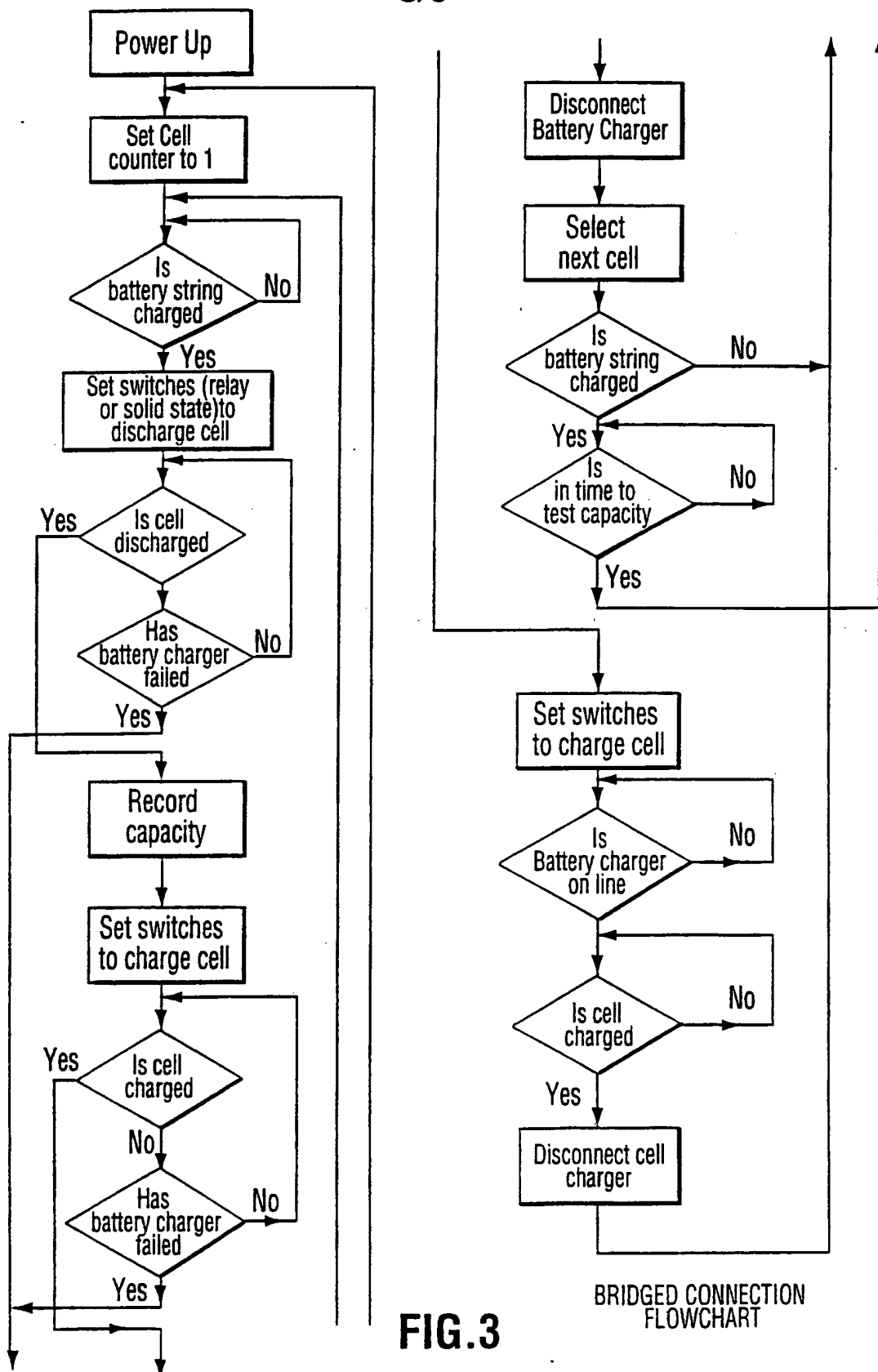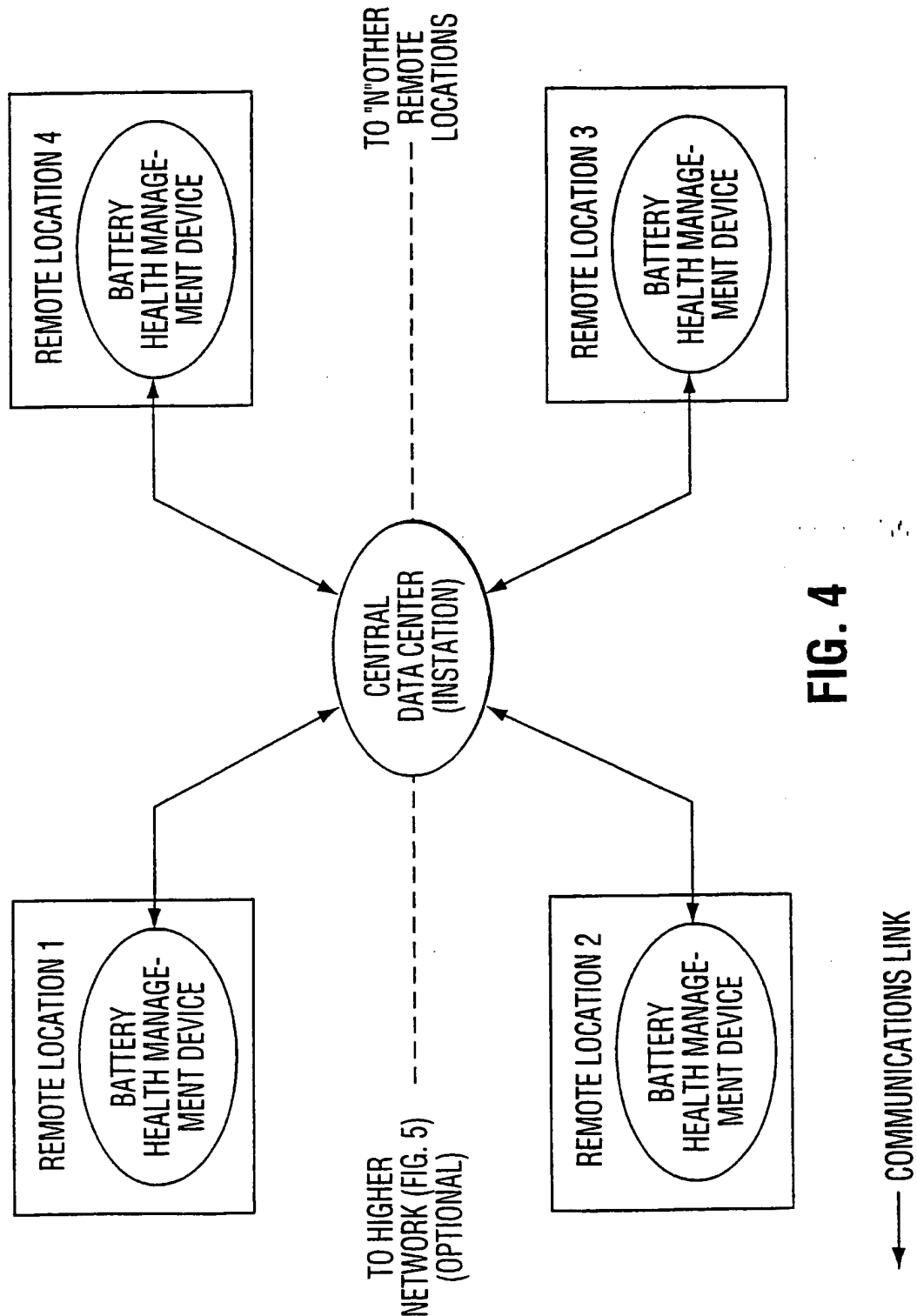
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FIG. 1

FIG. 2

Power Up

Set Cell counter to 1

Is battery string charged — No

Yes

Set switches (relay or solid state) to discharge cell

Is cell discharged — Yes

Has battery charger failed — No

Yes

Record capacity

Set switches to charge cell

Is cell charged — Yes

No

Has battery charger failed — No

Yes

Disconnect Battery Charger

Select next cell

Is battery string charged — No

Yes

Is in time to test capacity — No

Yes

Set switches to charge cell

Is Battery charger on line — No

Is cell charged — No

Yes

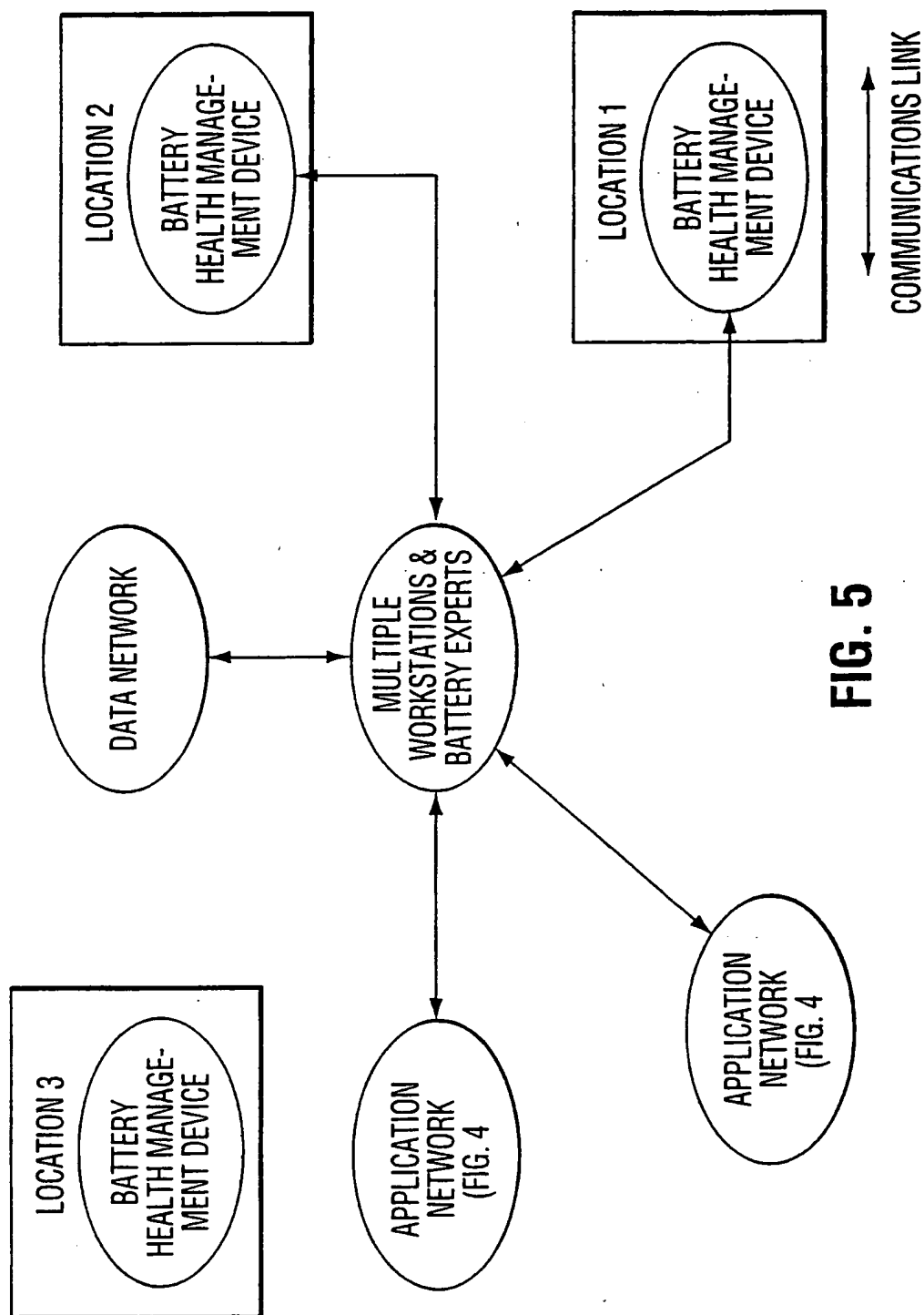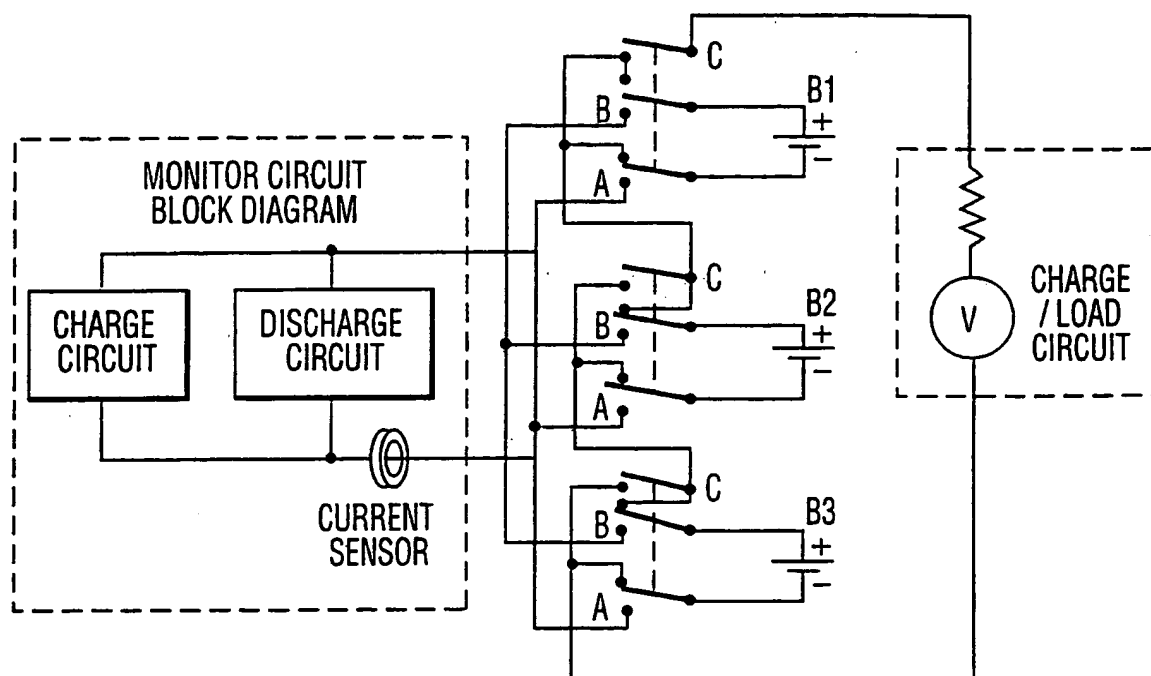**Disconnect cell charger**

BRIDGED CONNECTION
FLOWCHART

FIG.3

FIG. 4

FIG. 5

INSERTED CONNECTION CIRCUIT

FIG. 6